**INFORMATION OF RESEARCH RESULTS**

Dissertation title: STUDY ON MODELING AND FRACTIONAL-ORDER CONTROL FOR MULTIVARIABLE PROCESSES

Major : Mechanical Engineering Major code: 9520103

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**1. Thesis abstract**

Fractional calculus and its applications are interesting problems that attract researchers from many different fields. In the control field, fractional orders of integral and derivative terms are applied in the classical PID controller and extended to a general PID controller, with the orders of the derivative and integral terms being real numbers. Many studies have proposed this fractional-order controller, mainly for single-input, single-output systems. Meanwhile, industrial processes are mostly complicated multivariable systems because of the mutual effects of the process variables. As a result of that, controlling these systems is a challenge because it is difficult to manipulate each control loop independently. Various control structures and methods have been proposed, but this is still an open problem that needs to be researched intensively. In this thesis, the author suggests different solutions to solve the problems of multivariable systems using fractional-order controllers. The content of the thesis is summarized as follows:

- *Analyzing the necessity of fractional order in describing the dynamics of systems*, and the necessity of fractional calculus in the control field is also explained. *Research the effects of fractional-order derivatives and integrals on control signals in classical feedback controllers*. The simulation results show that the fractional-order controller makes the control signal flexible, less affected by disturbances, and also makes the entire control system more robust.

- Research decoupling techniques for multivariable systems, thereby *proposing a new control structure* that combines both the simplified decoupling technique and the Smith predictor to deal with existing delay times in real systems. The author *suggested to use particle swarm optimization (PSO) to reduce and simplify the transfer functions* of decoupling and decoupled matrices.

- *Propose fractional-order controllers and their tuning rules for multivariable systems*. In general, the author proposes two methods: for a 2×2 process using internal model control (IMC), and for 3×3 and 4×4 processes using multiple objective particle swarm optimization (MOPSO) with an objective function that meets the criteria of system performances and robustness simultaneously. The proposed methods are justified through simulation studies and also compared with other well-known methods using benchmark models in process control. The robust stability of the control systems is analyzed and evaluated by using the **M-Δ** structure with multiplicative output uncertainty.

- In addition, the applicability of the *proposed controller and fractional-order controllers is clarified by an experiment using the quadruple tank*. The least squares method for identification of single-input, single-output systems is extended to multivariate systems to derive the mathematical equations of the experimental model, from which the proposed methods are applied to derive the control parameters. The obtained controllers are adopted to control the system using the Real-Time Window Target of Matlab. The experimental results show that fractional-order controllers can be deployed in practical applications.

**2. New contributions of the thesis**

- The author has successfully proposed to *use the PSO algorithm to reduce and simplify the transfer functions* of the decoupling and decoupled matrices. This is to simplify calculations when the order of the system increases. The achieved simulation results demonstrate that the proposed method gives better approximation results than the methods of previous publications.

- Proposing *a new control structure for multivariable systems* that combines the simplified decoupling technique and the Smith predictor. Although the controller structure is relatively complicated, the performance is better when compared with other methods. *Proposing fractional-order controllers and parameter tuning methods for multivariable processes*. The author proposes two specific methods:

* For 2×2 multivariable systems, use *the internal model control (IMC) with the proposed fractional controller*. The analytical tuning rules are derived by using the desired time constant to compromise between the system response of the servomechanism problem (set-point changes) and the regulator problem (disturbance changes).
* With higher-order multivariable systems (3×3 and 4×4), use *multi-objective swarm optimization (MOPSO) to find control parameters* with the objective function that minimizes the error when both the set-point and disturbance change. The feasible solutions of the optimization problem will converge on the Pareto front, and from there, the appropriate solutions (control parameters) will be selected through the value of the maximum sensitivity function *Ms* to ensure the robust stability of the control systems.

- Research on *identification methods for multivariable systems by using the matrix fraction description (MFD)* technique to convert MIMO systems into multiple-input, single-output (MISO) systems. As a result of that, we can apply the common identification technique for single-variable systems (the least squares method) to identify multivariable systems. Applying the proposed identification method to for the quadruple tank. The *design method is experimentally verified for the quadruple tank* with a 2×2 transfer function matrix. The control results clearly demonstrate the practical applicability of fractional-order control as well as the proposed design method.